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Adapting ODC for Empirical Evaluation of Pre-Launch Anomalies

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Topics

- **Overview**
- **Results**
  - **Mars Exploration Rover**
  - **Deep Impact**
  - **Infusion of method**
  - **Dissemination of results**
- **Examples: Patterns and Lessons Learned**
- **Benefits**

Overview

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- **Goal:**
  1. **To characterize pre-launch software anomalies, using data from multiple spacecraft projects, by means of a defect-analysis technology called *Orthogonal Defect Classification (ODC).***
  2. **To support transfer of ODC to NASA projects through applications and demonstrations.**
- **Approach:**
  1. **Analyze anomaly data using adaptation of *Orthogonal Defect Classification (ODC)* method**
     - Developed at IBM; widely used by industry
     - Quantitative approach
     - Used here to detect patterns in anomaly data
     - More information at http://www.research.ibm.com/softeng
  2. **Adapt ODC for NASA use and apply to NASA projects**

Overview: *Status*

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- **Previous work used ODC to analyze safety-critical *post-launch* software anomalies on 7 spacecraft.**
- **FY'03 task extends ODC work to *pre-launch development and testing* (Mars Exploration Rover testing, Deep Impact, contractor-developed software) and to support *technology infusion***
- **Adapted ODC categories to spacecraft software at JPL:**
  - **Activity: what was taking place when anomaly occurred?**
  - **Trigger: what was the catalyst?**
  - **Target: what was fixed?**
  - **Type: what kind of fix was done?**

Results: *MER*

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- **Collaborating with Mars Exploration Rover to experimentally extend ODC approach to pre-launch software problem/failure testing reports (525 to date)**
  - **Adjusted ODC classifications to testing phases**
  - **Institutional defect database → Access database of data of interest → Excel spreadsheet with ODC categories → Pivot tables with multiple views of data**
  - **Frequency counts of Activity, Trigger, Target, Type, Trigger within Activity, Type within Target, etc.**
  - **User-selectable representation of results support tracking trends and progress:**
    - **Graphical summaries**
    - **Comparisons of testing phases**
  - **Provides rapid quantification of data**
  - **Project provides feedback/queries on our monthly deliverables of results and on our draft reports/paper**

Results: *Deep Impact*

- **Collaborating with Deep Impact to extend ODC approach into software developmental anomaly reports via ODC classification of development-phase SCRs (Software Change Re[redacted]rts) at Ball**
  - **Classified initial set of 94 critical DI SCRs (with highest cause-corrective action/failure effect ratings)**
  - **Feasibility check: ODC classification of development-stage software defects works well**
  - **Initial delivery to DI of ODC pivot table results (for browsing), of user instructions, and of initial issues/concerns**
  - **Project uses telecons/email to answer questions, suggest paths of interest to project**

Results: *Infusion*

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- **Gave invited presentation on ODC to JPL's Software Quality Initiative task as candidate defect-analysis tool**
- **Worked with manager/developers of next-generation JPL problem-reporting system to ensure that their web-based database will support projects' choice of ODC**
- **Carmen presented ODC to JPL's DII project (Defense Information Infrastructure); they requested followup presentation (given); Carmen is working with DII as they train their users & transition ODC into their operations**
- **Wide distribution to projects of slide summarizing use of ODC on MER (T. Menzies suggestion)**

Use on MER of ODC* defect analysis

Testing Problem Reports

Problem Report file for MER

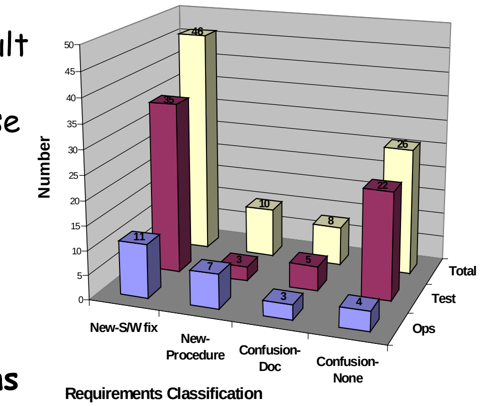
Classify MER test problem reports per ODC Categories

➢Where are the spikes?
➢Phase-by-phase deltas?
➢Activity/Trigger/Target/Type look nominal?

MER use: Browse pivot chart (Excel) for overview/closer look at testing

Discover defect patterns in testing of interest to MER

➢How many problem reports result in requirements discovery?
➢Improvement release-by-release uneven: why?
➢Many closed with no fix: why?



MER use: Identify patterns of concern for more investigation

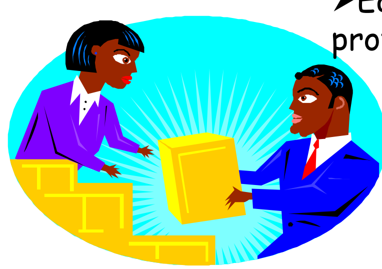
Perform Root Cause Analysis on subset

MER use: Improved understanding of data, underlying causes, defect mechanisms

• Develop and package recommendations for MER

Recommendations for MER and future projects:
➢Earlier assignment of criticality ratings
➢If software's behavior confused testers, enhance documentation
➢Earlier testing of fault-protection

MER use: Implement/defer recommendations



*ODC = Orthogonal Defect Classification technique [IBM]

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Results: *Dissemination*

- **Presented paper on the 4 mechanisms involved in requirements discovery during testing at ICSE 2003 (Int'l Conf on S/W Eng)**
- **Presented paper on patterns of defect data at SMC-IT 2003 (Space Mission Challenges)**
- **Presented results at JPL/GSFC QMSW 2003 (Quality Mission Software Workshop)**
- **T. Menzies presented analysis of the ODC defect data at SEKE 2003 (Int'l Conf S/W Eng & Knowledge Eng)**
- **Paper on how operational anomalies drive requirements evolution appeared in Journal of Systems and Software, Feb. 2003**
- **Paper describing similar mechanisms in testing & ops anomalies accepted to RE 2003 (Int'l Requirements Eng Conf); selected as one of best experience papers & paper invited for IEEE Software submission**

Example: Testing Defect Patterns

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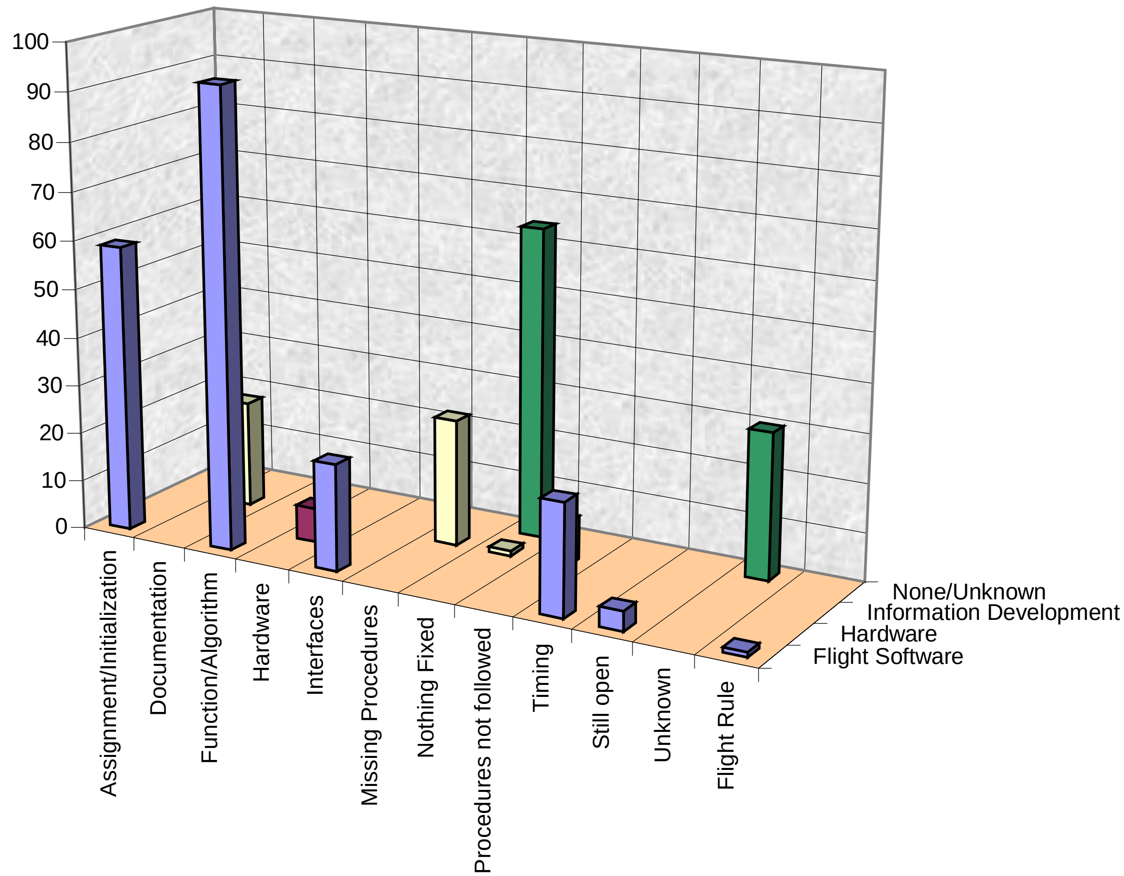
Distribution of Types by Target



Example: Lessons Learned from ODC

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- **Testing reports give "crystal ball" into operations**
  - **False-positive testing problem reports (where software behavior is correct but unexpected) provide insights into requirements confusions on the part of users**
  - **If software behavior surprised testers, it may surprise operators**
- **Closing problem reports with "No-Fix-Needed" decision can waste opportunity to document /train/ change procedure**
  - **Avoid potentially hazardous recurrence**
  - **Important in long-lived systems with turnover, loss of knowledge**

Benefits

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- **Experience: Applied to 9 NASA projects**
  - **Development, testing, and operations phases**
- **Level of effort affordable**
  - **Uses existing fields in existing problem-reporting system)**
  - **ODC ~ 4 minutes/defect vs. Root cause ~ 19 (Leszak & Perry 2003)**
- **Uses metrics information to identify and focus on problem patterns**
  - **Incorporates project results into multi-project baseline patterns to provide guidance to future projects**
  - **Can answer current project's questions regarding defects**
- **Flexible**
  - **Visualization & browsing options**
- **Provides quantitative foundation for process improvement**
- **Equips us with a methodology to continue to learn as projects and processes evolve**

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Backup Slides

Results

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- **2 basic kinds of requirements discovery:**
  - **Discovery of *new* (previously unrecognized) requirements or requirements knowledge**
  - **Discovery of *misunderstandings* of (existing) requirements**
- **Reflected in ODC Target (what gets fixed) and ODC Type (nature of the fix):**
  1. Software change **(new requirement allocated to software)**
  2. Procedural change **(new requirement allocated to operational procedure)**
  3. Document change **(requirements confusion addressed via improved documentation)**
  4. No change needed

Results: Examples

1. **Incomplete requirements, resolved by change to software:**

   New software requirement became evident: initial state of a component's state machine must wait for the associated motor's initial move to complete

2. **Unexpected requirements interaction, resolved by changes to operational procedures:**

   Software fault monitor issued redundant off commands from a particular state (correct but undesirable behavior). Corrective action was to prevent redundant commands procedurally by selecting limits that avoid that state in operations

Results: Examples

3. Requirements confusion, resolved by changes to documentation
   - Testing personnel incorrectly thought heaters would stay on as software transitioned from pre-separation to Entry/Descent mode; clarified in documentation.
4. Requirements confusion, resolved without change
   - Testers assumed commands issued when component was off would be rejected, but commands executed upon reboot. No fix needed; behavior correct.